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COMMERCIAL HUMAN SPACEFLIGHT SAFETY REGULATIONS: FEDERAL AVIATION ADMINISTRATION PERSPECTIVE

John Sloan
Federal Aviation Administration, Office of Commercial Space Transportation (FAA/AST), Washington, DC, United States, john.sloan@faa.gov

Dr. George Nield
Federal Aviation Administration, Office of Commercial Space Transportation (FAA/AST), Washington, DC, United States, george.nield@faa.gov

The arrival of commercially operated space transportation systems that carry people gets closer each year. The needs and goals of a commercial space enterprise may be quite different from those of a government space program. A commercial operator flying space tourists or carrying cargo or people will have different approaches on how to achieve success as compared to a government program. In the United States, a balance has been struck between the development needs of a fledgling commercial space transportation industry and that of public safety. Unlike the origins of aviation, the birth of a commercial human space flight industry is occurring with a strong foundation of safety regulations already established. However, much remains to be learned when regular space flights occur and as the industry expands. This paper describes the U.S. foundation (law, regulations, policy and general philosophy) currently in place and highlights three current activities and issue areas as examples in regulating commercial human space flight. The near-term issues included in this paper are: 1) suborbital and orbital environmental control and life support systems (ECLSS); 2) human rating; and 3) defining commercial launch as it relates to the roles of the Federal Aviation Administration (FAA) and the National Aeronautics and Space Administration (NASA) in the proposed NASA commercial crew program. The FAA has responsibility for protecting public safety by regulating commercial space launch and reentry in the United States (or by regulating U.S. citizens operating outside the United States). In 2004, the U.S. Congress passed the Commercial Space Launch Amendments Act (CSLAA) of 2004. In response to the CSLAA, the Federal Aviation Administration (part of the U.S. Department of Transportation) issued new regulations which became effective in 2007. These regulations established requirements for crew and space flight participants in private human space flight as part of a phased approach to regulating an industry that will grow and evolve over time.

I. Introduction

Human space activity is in a transition period as it expands from a government-only realm into a commercial business. Government regulation of this commercial activity faces increased challenges in order to preserve public safety while balancing the growth of commercial enterprise. As commercially operated human space flights for both suborbital and orbital flight on a regular basis moves closer to reality, governments are confronted with options to guide this emerging industry.

In the U.S., the Federal Aviation Administration (FAA) has responsibility for protecting public safety by regulating commercial space launch and reentry as well as commercial spaceports. The FAA will also license U.S. citizens (or companies) operating outside the United States if they are conducting a launch or reentry or operating a spaceport. The FAA also

promotes U.S. commercial space transportation.

This paper provides a background on how the U.S. has approached regulation to date and includes three near-term issues as examples in regulating commercial human space flight from a United States perspective. The three issues involve suborbital and orbital environmental control and life support systems (ECLSS), human rating, and the definition of a commercial launch related to the roles of the FAA and NASA in the proposed commercial crew program.

II. The U.S. Approach to Regulating Commercial Space Transportation

The United States was the first country to establish commercial space transportation regulations. Australia, France and Japan have passed laws to regulate commercial activities in space and other countries such as Sweden and the United Kingdom are developing or considering some form of commercial space transportation regulations.

In 2008, the European Aviation Safety Agency (EASA) indicated its intent to flight certify winged space launch vehicles that use European airspace. "Sub-orbital Aeroplanes deriving support from the atmosphere for the largest part of their flight, are considered as aircraft by EASA.[1]

That approach differs from existing law, regulation, philosophy, and policy in the United States. Title 49, Subtitle IX, chapter 701 of the U.S. Code 49 (formerly the Commercial Space Launch Act of 1984, as amended) authorizes Secretary of Transportation to regulate commercial space launches and reentries. This authority is delegated to the Federal Aviation Administration's Office of Commercial Space Transportation (AST). The law states that the FAA is only to regulate "to the extent necessary."[2] The U.S. Congress has only incrementally expanded the FAA's authority. It gave the agency authority to regulate launch in 1984 and granted reentry authority in 1998. Congress confirmed the FAA's authority over commercial human space flight with the passage of the Commercial Space Launch Amendments Act (CSLAA) of 2004. The CSLAA limits the extent to which the FAA can regulate the safety of persons on board vehicles until 2012. The CSLAA also states that "the regulatory standards governing human space flight must evolve as the industry matures so that regulations neither stifle technology development nor expose crew or space flight participants to avoidable risks as the public comes to expect greater safety for crew and space flight participants from the industry."[3, 4]

The aviation side of the FAA certifies airplanes for safety. In its practice of regulating commercial space launches however, FAA/AST does not certify commercial space launch or reentry vehicles. It instead licenses the launch and reentry event to protect public health and safety. While the FAA does have technical requirements in its regulations (such as for safety-related systems), the commercial launch or reentry operator has the responsibility for vehicle design. This approach is also different from the space launch sides of NASA and the Air Force which are involved in design to ensure mission success. In a commercial launch, mission success is the responsibility of the commercial operator.

These somewhat "hands-off" approaches also reflect a general U.S. business philosophy. To maximize the innovative potential of the U.S. private sector and in particular, entrepreneurs, the U.S. Government attempts to stay out of the way of private industry.

Current U.S. policies regarding commercial space launch activity (the 2010 National Space Policy and the 2004 U.S. Space Transportation Policy) contain several guidelines for U.S. government agencies. These include: purchase of commercial

services to the maximum practical extent, exploring the use of inventive, non-traditional arrangements to acquire space goods and services, transferring routine operations to the commercial sector, and refraining from competing with commercial space activities unless required by national security or public safety.[5] In addition, the Commercial Space Act of 1998 directs the U.S. federal government to: "acquire space transportation services from United States commercial providers whenever such services are required in the course of its activities. To the maximum extent practicable, the Federal Government shall plan missions to accommodate the space transportation services capabilities of United States commercial providers."[6]

II. Environmental Control and Life Support Systems

Current activities and issues in commercial human space flight illustrate the U.S. regulatory approach. The first involves environmental control and life support systems (ECLSS).

The FAA has the authority to promulgate regulations to protect the crew when they are part of the flight safety system that protects the general public. In response to the CSLAA, the FAA established the requirements of 14 CFR § 460.11, which included requirements for governing ECLSS to ensure atmospheric conditions adequate to sustain life and consciousness for all inhabited areas within a vehicle. The requirements are performance based rather than design specific. In other words, the requirements do not contain prescriptive design solutions.

In 2010, the FAA released guidelines for the design and development of ECLSS for suborbital human spaceflights.[7] The guidelines recommend that an operator or flight crew to monitor and control specific atmospheric conditions or to demonstrate through the license or permit process that an alternative means of compliance provides an equivalent level of safety.

Pressure Suits

Different suborbital operators have different objectives and missions that affect the design of their vehicle and ECLSS. One consideration industry has in suborbital human space flight is whether to use pressure suits.

The 2010 suborbital guidance does not recommend for or against pressure suits. The guidance states that: "Total loss of cabin pressure at altitudes above 40,000 feet altitude without the protection of a pressure suit will most likely result in a fatal accident, however, use of pressure suits in a low-pressure operating environment brings a unique set of operational concerns that applicants may consider. A survey of more than 400 U-2 pilots found that 75% reported in-flight symptoms of decompression sickness throughout their careers that resolved upon descent to lower altitudes, and about 13% of them reported that they altered or aborted their missions as a result. Regular use of suits may entail a complex maintenance regimen such that suits may be a liability for an operator if they are not regularly tested and maintained. Unless human factors and design are considered for both the suit and the aircraft, pressure suits may adversely affect the ability of flight crew to perform certain safety-critical functions by limiting range of motion, response time, communications, visibility, reach, tactile sensitivity, applied force, or hand-eye coordination. Heat dissipation may also be an operating concern with partial-pressure suits, depending on the design, operating environment, user workload, and degree of user control."[8]

Under the 2004 CSLAA, even if it wanted to, the FAA currently cannot require space flight participants to wear pressure suits since it does not have authority to protect space flight participants. "The CSLAA only allows the FAA to issue regulations restricting or prohibiting design features or

operating practices that result in a human space flight incident or a fatality or serious injury to space flight participants during an FAA authorized flight until December 23, 2012."[9] Use of pressure suits is an option available to industry and may remain so in the foreseeable future.

Orbital commercial spaceflight is different than suborbital spaceflight because the orbital environment poses increased challenges to system performance and reliability. For example, orbital flights require much greater velocity and experience greater reentry heating loads compared to suborbital flights. A speed of Mach 25 is needed to reach orbit while suborbital space tourism flights may only have speeds around Mach 3. In addition, the amount of time spent in space during each suborbital flight may only be minutes while the amount of time in orbital flight could be measured in days.

III. Commercial Crew Requirements

The Obama Administration raised the prospect of commercially operated crew missions to low Earth orbit and the International Space Station (ISS) that could carry NASA astronauts in the Fiscal Year 2011 budget request for NASA. NASA has been preparing to meet the challenge of "human rating certification" for launch and reentry vehicles in a commercial paradigm. The issue is of interest to not only NASA but partner nations of the ISS and their respective astronauts and cosmonauts that could also someday fly on commercial vehicles. In addition, private operators of future commercial space habitats or transportation vehicles are also interested.

Congress has not yet decided on the fate of the commercial crew proposal and the FAA, industry and NASA are continuing discussions on safety requirements. While this is occurring, there are some points to keep in mind.

Both agencies have complementary objectives. The FAA regulates and promotes U.S. commercial space transportation and NASA's mission is to pioneer the future in space exploration, scientific discovery and aeronautics research.

The FAA has a solid space foundation in its background. Existing law dates to 1984 and enabling regulations govern expendable launch vehicles, reentry vehicles, reusable launch vehicles, spaceports and commercial human space flight. Furthermore, the FAA has licensed over 200 commercial space launches since 1989. It licensed SpaceShipOne, the first privately-built space vehicle to carry people. The FAA will license missions to the ISS under NASA's Commercial Orbital Transportation Services (COTS) program and Cargo Resupply Services (CRS) program that can demonstrate success before commercial crew missions begin. The FAA has processes for determining insurance requirements and executing cross-waivers. There is government indemnification, which is subject to appropriations for third-party excess claims. If needed, the FAA has authority to enforce compliance with its regulations. The FAA has decades of aviation regulatory experience which in some cases is applicable to space flight. Certainly, the FAA has and will continue to seek NASA's advice based on its decades of human space flight experience.

For the commercial crew program, U.S. commercial industry itself in many cases has decades of experience in building and operating hardware and software used in government space programs.[10] Industry is also realistic and open about the need for NASA involvement that is properly balanced.[11]

As a customer, NASA has the option to establish additional requirements for the commercial launch vehicle operator through a contract for services. Bryan O'Connor, NASA's Chief of the Office of Safety and Mission Assurance, indicated in 2010 that NASA is open to industry alternatives. NASA "…will accept ideas on equivalents.

There are very few mandatory standards that we will not accept ideas on tailoring. There are some we don't have authority to tailor, in the safety and medical areas, but there are hardly any in what I call the basic engineering requirements and standards."[12]

NASA issued a Request for Information to U.S. industry detailing its requirements and standards for human rating in May 2010. The FAA has suggested that U.S. industry develop consensus standards based on NASA's RFI that provide a basic safety foundation that the FAA could reissue as guidance documents. These could lead to eventual FAA regulations.[13]

Defining Commercial Launch

Connected to the discussion on rating requirements, the question of what makes a space launch "government" or "commercial" has also arisen. The current process traces back to: 1) 49 U.S.C. § 70177 states government missions are those the U.S. government conducts and that are for the U.S. government; [14] and 2) a 1990 decision by the U.S. Department of Justice on "substantial involvement."

Since 1989, the FAA has licensed 27 launches for various U.S. Government customers. These missions were done by a commercial launch operator for the government, often under a Delivery-in-Orbit-type contract. Under this kind of contract, the government sets initial requirements and then takes a hands-off role with some insight after contract award. The contractor is responsible for procuring the satellite manufacturer and launch provider and checks out the satellite after launch. The government then receives a working satellite in orbit. Going the commercial route is a choice of the government.

In 1990, DOT licensed a commercial launch of NASA's Combined Release and Radiation Effects (CRRES) science satellite. After a request by NASA, the Department of Justice determined the government had "substantial involvement" in the CRRES launch and it did not need a commercial license.

As seen in the FY 2011 budget request, the intention of the Obama Administration with the commercial crew program is to have a commercial operator provide services to NASA, similar to the COTS program and not as a traditional government cost-plus contract. "The Commercial Crew Program will provide $6 billion over the next five years to support the development of commercial crew transportation providers to whom NASA could competitively award a crew transportation services contract analogous to the Cargo Resupply Services contract for ISS. These funds will be competed through COTS-like, fixed-price, milestone-based Space Act Agreements that support the development, testing, and demonstration of multiple commercial crew systems."[15] NASA later said there could be one or more service contracts and it expects the commercial partner to provide an end-to-end solution "to do integration of all flight hardware and flight and ground operations support."[16]

However, the budget request also states that: "At no point in the development and acquisition of commercial crew transportation services will NASA compromise crew safety. NASA has unique expertise and history in this area, and a clearly demonstrated record of success. NASA will bring that experience to bear in the appropriate way to make sure that commercial crew transportation services are a success both programmatically, and with respect to safety." As a result, NASA is an involved customer seeking human rating certification (also known as Crew Transportation System certification) and approval over launch of NASA astronauts. NASA plans to have embedded insight teams with the commercial partner but has a goal of buying commercial services.[17]

The timeline for when the FAA would license commercial crew missions is unclear. During 2010, NASA statements

refer to "eventual licensing" of commercial crew missions. Presentations by NASA include framework goals such as the following: "Obtain NASA human spaceflight certification for ISS crew transportation missions. This will not cover the certification of other NASA missions or non-NASA missions" and "Accommodate eventual Federal Aviation Administration (FAA) licensing with NASA human spaceflight certification and NASA technical mission assurance oversight."[18]

IV. Future Activity

In setting an eight-year moratorium on allowing the FAA to establish regulations to protect space flight participants, the U.S. Congress hoped that by 2012 there would be several commercial human space flights for industry and the FAA to learn and gain experience from. But no additional licensed (or permitted) flights with people onboard have taken place since SpaceShipOne in 2004.

Nevertheless, U.S. industry has been very active and is getting closer to flight activity. Virgin Galactic, XCOR Aerospace, Masten Space Systems, Armadillo Aerospace and others are developing and testing suborbital vehicle hardware. SpaceX and Orbital Sciences are developing new vehicles for ISS resupply with cargo return capability. Although it is unknown how many companies will bid for future commercial crew missions, NASA received 35 responses to a 2010 NASA Request for Information.[19]

The 2007 FAA regulations cover a variety of subjects including crew and space flight participant training, medical standards for crew, risk to space flight participants, informed consent, and waiver of claims. The FAA is continuing to assess these regulations and future requirements in order to continuously improve safety.

Experience in aviation tells us that it takes time through actual flights and lessons learned to develop the most effective best practices and regulations. Commercial human space flight is expected to be similar.

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[1] Marciaq, Jean-Bruno, et. al., "Accommodating Sub-Orbital Flights into the EASA Regulatory System," International Association for the Advancement of Space Safety (IAASS) Conference, October 2008, S09-05, page 3.

[2] Title 49, Subtitle IX, Chapter 701, Section 70101, (a) (7). The text states that: "the United States should encourage private sector launches, reentries, and associated services and, only to the extent necessary, regulate those launches, reentries, and services to ensure compliance with international obligations of the United States and to protect the public health and safety, safety of property, and national security and foreign policy interests of the United States." http://www.faa.gov/about/office_org/headquarters_offices/ast/regulations/

[3] Ibid., (a) (15).

[4] For more information on the history of FAA commercial space transportation regulations, see Nield, George; Owens, D. Brooke; and Sloan, John; "The Origin and Practice of U.S. Commercial Human Space Flight Regulations," Federal Aviation Administration, International Astronautical Congress, 2008. The office in charge of commercial space transportation began in the Office of the Secretary of Transportation and was transferred to the FAA in 1995.

[5] National Space Policy of the United States of America, June 28, 2010, page 10. http://www.whitehouse.gov/sites/default/files/national_space_policy_6-28-10.pdf and http://www.whitehouse.gov/the-press-office/fact-sheet-national-space-policy. U.S. Space Transportation Policy, 2004, page 6. http://www.whitehouse.gov/administration/eop/ostp/library/archives

[6] Commercial Space Act of 1998, Public Law 105-303. Available at http://www.nasa.gov/offices/ogc/commercial/CommercialSpaceActof1998.html. Although still in effect, the law also lists seven exceptions to the use of U.S. commercial space transportation.

[7] Federal Aviation Administration, "Environmental Control and Life Support Systems for Flight Crew and Space Flight Participants in Suborbital Space Flight," Version 1.0, April 2010. Available at http://www.faa.gov/go/ast

[8] Ibid., page 10.
[9] "Human Space Flight Requirements for Crew and Space Flight Participants," *Federal Register*, December 15, 2006, pages 75624/ Available from http://www.faa.gov/about/office_org/headquarters_offices/ast/human_space_flight_reqs/
[10] "Statement of Dr. George C. Nield, Associate Administrator for Commercial Space Transportation, before the U.S. Senate Committee on Commerce, Science, and Transportation, Subcommittee on Science and Space," March 18, 2010. Available at: http://commerce.senate.gov/public/index.cfm?p=Hearings or http://www.faa.gov/news/testimony/news_story.cfm?newsId=11254
[11] See for example, Orbital Sciences prepared U.S. Senate testimony from former astronaut Frank Culbertson on March 8, 2010, available at http://legislative.nasa.gov/hearings/index.html and statements by Brett Alexander of the Commercial Spaceflight Federation to a House Science subcommittee n December 2009 available at http://science.house.gov/publications/hearings_markups_details.aspx?NewsID=2693
[12] "Human Rating," *Aerospace America* July/August 2010, page 27. Transcript of a May 24, 2010 roundtable. http://www.aerospaceamerica.org/Documents/July%202010/Human_Rating_Feature.pdf
[13] Ibid., page 28.
[14] In addition, Title 49 states that: " (1) "citizen of the United States" means - (A) an individual who is a citizen of the United States; (B) an entity organized or existing under the laws of the United States or a State; or (C) an entity organized or existing under the laws of a foreign country if the controlling interest (as defined by the Secretary of Transportation) is held by an individual or entity described in subclause (A) or (B) of this clause." 49 US Code, Subtitle IX, Section 70102. http://www.faa.gov/about/office_org/headquarters_offices/ast/regulations/
[15] NASA Fiscal Year 2011 Budget Estimates, February 2010, page XP-14 (pdf page 349 of 517). http://www.nasa.gov/news/budget/index.html
[16] NASA "Commercial Crew Planning Status Forum" NASA Exploration Systems Mission Directorate, briefing charts, August 19, 2010, page 17. http://www.nasa.gov/exploration/new_space_enterprise/commercial/cc_forum.html
[17] Ibid., pages 32-33.
[18] Ibid., page 6.
[19] NASA "Commercial Crew Planning Status Forum" NASA Exploration Systems Mission Directorate, briefing charts, August 19, 2010, page 11. http://www.nasa.gov/exploration/new_space_enterprise/commercial/cc_forum.html